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From Control to Management: changes in Dutch Flood Mitigation

Anthony Kuster

FROM CONTROL TO MANAGEMENT: CHANGES IN DUTCH FLOOD MITIGATION

Anthony Kuster

"God created the world, but the Dutch created the Netherlands."
— old English adage

Introduction

On the night of January 31, 1953, a dynamic weather system with strong winds, in combination with a high tide, caused extensive flooding in the province of Zeeland, located along the southwest coast of the Netherlands. Storm surge[1] from the North Sea brought water levels to a record height of 4.55 meters above sea level, and many dikes failed due to overtopping and extensive wave battering. (Deltawerken Online) As a result, 1,835 people died. Over 750,000 inhabitants were affected, 500,000 acres of land were inundated, and the country experienced 1.5 billion guilders ((680 million in 2007) in direct economic losses. (Bijker, p. 571) This was not the first time a large flood caused extensive damage and loss of lives; the Dutch have been battling water for their entire history. In fact, water poses a "double threat" to the Netherlands, with floods arising from both the sea and from the rivers which flow through the country.

Located in northwest Europe along the North Sea, the Netherlands is situated on a series of deltas from four major rivers — the Rhine, Meuse, Scheldt, and Ems. Called *Nederland*, which is Dutch for "low lands," about two-thirds of the country's 34,000 square kilometers of land is located below mean sea level. (Walker et al., p. 824) Additionally, the Netherlands is one of the most densely-populated countries in the world with 489 people per square kilometer of land.

[1]Storm surge is the rise in water level caused by the combination of strong winds and decreased atmospheric pressure.

Figure 1

Floodable Land without Flood Defenses

Source: "Water in the Netherlands 2004–2005: Facts and Figures."

(World Fact Book . . .) With a large proportion of its 16 million inhabitants located in flood-prone areas, it is estimated that 70 percent of the gross domestic product is earned in areas at or below sea level. (Waterland.net) Combined, these factors make the country extremely vulnerable to flooding disasters, which have forced engineers to develop innovative solutions.

To protect themselves, the Dutch have erected over 3,500 kilometers of primary flood defenses, which include dikes,[2] dunes, flood barriers, and dams. ("Water in the Netherlands

[2]Dikes, or levees in American English, are raised embankments along a waterway which restrain floodwaters from inundating surrounding lowlands.

. . . ," p. 14) They serve to protect the country from the major rivers, lakes, and the sea. In Figure 1, the darker colored areas represent land that would flood if it were not for primary flood defenses. Without such defenses, 70 percent of the country would be regularly under water. (Waterland.net) This elaborate system of flood protection has developed over the past millennium, beginning with small democratic water boards, known as *waterschappen*. These organizations, in which each landowner had one vote, were responsible for the building and maintenance of dikes around a polder.[3] This decentralized system was effective in managing local flood problems; however, *waterschappen* were not capable of uniting to coordinate major flood protection projects together. (Disco and van den Ende, p. 505)

To construct the major public works necessary to fight flooding, the Dutch needed a centralized authority with more abundant resources. That agency is the *Rijkswaterstaat*, which was created in 1798, as its charter states, "for the administration of all that which pertains to public works" under the slogan "unity, simplicity, and indivisibility." (Lintsen, p. 554) Since its creation, this large civil service organization has left a decisive mark on the Dutch countryside. Numerous structural works dominate the landscape, including dikes, weirs, locks, storm surge barriers, bridges, and viaducts — all of which serve to mitigate flooding and provide infrastructure to the Dutch people.

Historically, the Dutch have dealt with flooding by building increasingly larger structures. If a large river flood overtopped a dike, they would build a bigger one. If a strong storm pushed a storm surge inland, they would build a barrier. Of course, as the size of the project increases, so does its cost and impact. This trend cannot continue, however, and the Dutch have realized that. In this article, I examine the changes associated with flood control techniques that are currently being implemented in the Netherlands. I discuss the historical approaches and analyze a number of recent policy changes. Finally, I offer some suggestions for the future and discuss upcoming challenges that the Dutch may face in successfully transitioning their flood mitigation techniques.

Background

Types of Floods

There are two distinct sources of floods in the Netherlands: internal flooding, or river floods, and external flooding, or North Sea floods. Internal flooding occurs as a result of excess rainfall runoff quantities being great enough over a sufficiently short period of time to exceed a river's capacity. If a river is very long (such as the Rhine, which drains water from parts of nine countries), heavy rain in one area can result in flooding far downstream. ("Water in the Netherlands . . . ," p. 39) Recent examples of Dutch internal floods are those that occurred in 1993 and 1995 following heavy winter storms. The flood of 1995 brought flow rates in the Rhine to six times its average discharge and forced the evacuation of 250,000 inhabitants and their livestock, as authorities feared dikes would collapse. ("Water in the Netherlands . . . ," p. 23) While no major breaches occurred, the incidents were a wake-up call for Dutch river dike reform.

Most Dutch riverbanks were lined with dikes as early as the fourteenth century. These dikes provided some protection, but recurrent flooding continued as sandbars and bottlenecks developed. (Lintsen, p. 552) Engineers of the early *Rijkswaterstaat* needed to decide whether to create overflow areas, where excess floodwater ran across uninhabited land, or to deepen the problematic rivers. (Lintsen, p. 556) The fateful decision was made, and in the second half of the nineteenth century a major project was undertaken by the *Rijkswaterstaat* in which hundreds of kilometers of river were systematically reshaped, each receiving a standard width and depth. Additionally, new estuaries were dredged for the Rhine and Meuse rivers to provide additional connections between the rivers and the sea. Again in the 1930s the rivers were reshaped. Some bends were removed, and new dams were built. (Lintsen, p. 563) By creating a complicated network of rivers and

[3]A polder is a piece of land reclaimed from the sea, located below the surrounding water level and encompassed by dikes. The land must constantly be drained to keep the water table from inundating the land.

canals, the Dutch are able to control discharges with a series of sluices by diverting water from branches with high flows to those with lower water levels. In combination with dikes having heights designed to handle water levels that occur, on average, every 250 to 1,250 years, this nature-altering strategy has protected the Dutch from internal flooding for most of the twentieth century. The near-disastrous floods of 1993 and 1995, however, may be indications that increasing dike height may not be a realistic solution for the future.

The second type of flooding, external flooding, has a more notorious history. With powerful storms that rip through the English Channel with high winds, the North Sea has traditionally been viewed as an enemy. These external floods come as a result of storm surge pushing water from the sea inland and breaching protective dunes and dikes. When the land behind the protection lies below sea level, as is the case in the Netherlands, the flooding is exacerbated. Folklore from the Middle Ages repeatedly pits the Dutch against the sea in legends that are usually the result of many catastrophic floods. In some of the more horrific accounts dating as far back as A.D. 838, tens of thousands of people are estimated to have lost their lives in floods. (Deltawerken Online) The most notable example of external flooding, however, is the North Sea Flood of 1953. As a result of this catastrophe, sweeping changes came about in Dutch design criteria and flood control techniques. These changes have been encompassed in the Delta Project.

The Delta Project[4]

Three weeks following the 1953 disaster, a government commission was created to investigate the causes of the flood and give advice to improve flood protection techniques. Within 20 days, the Delta Commission, as it was called, issued an interim version of what would become the Delta Plan. Named by the creative director of the *Rijkswaterstaat*, A.G. Maris, the Delta Plan acquired such a sense of urgency and a need for change that even today the Dutch use "Delta Plan" to refer to anything that requires a major change, including art restoration and river dike safety. (Bijker, p. 577) The Plan called for the closure of all estuaries in order to shorten the coastline by 800 kilometers. (Waterland.net) In effect, the Dutch were building a continuous, rigid "wall against the sea." The only exceptions were the two estuaries which connect Antwerp and Rotterdam to the North Sea. While safety was the top priority, the economic importance of these two immense ports required uninhibited access to the sea. To fulfill the Commission's recommendations, a series of dams and barriers, known as the Delta Works,[5] was constructed along the southern Dutch coast. Costing a total of (5 billion, the Delta Plan not only changed the face of Holland, but also changed the way the Dutch designed flood protection. (Jans)

First, each dike ring[6] was assigned a safety level. The safety level was described as the probability that a certain water level would be reached or exceeded in any given year, based on historical data. Depending on the ring, these values ranged between 1 in 1,250 and 1 in 10,000. Areas with high concentrations of population and valuable assests, such as airports or industrial centers, were assigned higher safety levels. For example, Dike Ring 14 is home to 3.2 million residents and includes the major cities of Amsterdam, Rotterdam, and The Hague. Additionally, the area is heavily industrialized. (van Westen, p. 23) For such a critical dike ring, the Dutch designed the dikes for water levels that should be exceeded, on average, only once every 10,000 years. By assigning different safety levels throughout the country, the Dutch prioritized spending, thus improving efficiency. Additionally, the method by which the Dutch designed the dikes also revolutionized flood control, as I explain below.

By applying cost-benefit analysis to flood control design, the *Rijkswaterstaat* systematically improved its own efficiency and effective-

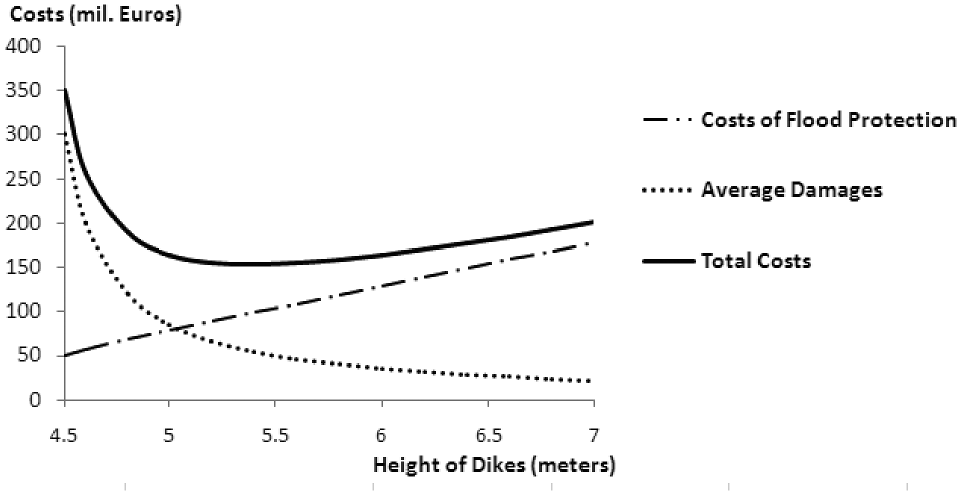
[4]Unless otherwise noted, the information in this section can be found in Smits, Nienhuis, and Saeijs, "Changing Estuaries, Changing Views."

[5]Known as the *Deltawerken* in Dutch, the Delta Works is the largest water protection project in the world. For more information on each component, see Deltawerken.com.

[6]The Netherlands is divided into 53 regions, known as dike rings. Each is entirely surrounded by a continuous system of dikes, which form a "ring" around the area. They vary greatly in area and population.

Figure 2

Cost-Benefit Analysis of Dike Construction



Source: Kuijpers, Remarks to Martindale Students, May 16, 2007.

ness. Once a safety level was determined for each dike ring, the water level corresponding to that safety level was calculated. Take, for example, Dike Ring 14 and its 1-in-10,000-year safety level. Using historical weather data, land contours, and models, the *Rijkswaterstaat* calculated a water level that should have a 1-in-10,000 probability of occuring or being exceeded in any given year. The agency then determined the value of damages to property within the ring as a function of dike height. Thus, as the dike height increases, the value of the damages decreases, because water is breaching the dike less frequently. For example, if it is assumed that the 10,000-year water level is six meters (Figure 2), the average damages curve depicted in Figure 2 can be observed to level off considerably at dike heights greater than six meters. The reason is that if the water level is six meters, there is theoretically no greater protection from a seven-meter dike than from a six-meter dike. Next, the cost of dike construction was determined as a function of dike height. Of course, this curve increases with dike height. By summing these two curves, as seen in Figure 2, a total cost curve is created. The minimum value of the total costs, seen here to be between 5.0 and 5.5 meters, is the optimum dike height using cost-benefit analysis. Notice that the 10,000-year dike height is less than the 10,000-year water level. The reason is that the marginal cost of building a higher dike is greater than the marginal benefit (decreased damages) of building a higher dike.

Using this approach the Dutch have continued their millenium-long pattern of land reclamation and structural defense against the sea, ultimately culminating with the completion of the Maeslant Barrier in 1997. Protecting the *Nieuwe Waterweg*, the waterway which gives access to the port of Rotterdam, this moveable barrier has four times the amount of steel in the Eiffel Tower and has the world's two largest ball bearings, each weighing 680 tons. (Deltawerken.com) The Dutch had built moveable storm surge barriers before — the first was constructed on the *Hollandse IJssel* in 1958 — but never ones of this size. Celebrated as a triumph for the Netherlands, the completion of the Maeslant Barrier meant that the Delta Project was finally complete.

The Delta Project's closing of estuaries was hailed as a success for Dutch flood safety; no external floods have afflicted the country since the Project's inception in 1953. Over that period, however, many other problems have been experienced. First, by closing estuaries to the sea, the barriers disrupted the existing ecosystems.

Normally, changing tides create a transition zone between salt and fresh waters, which develops a diverse habitat for a variety of species. By erecting a barrier, the salinity of the water is greatly affected, resulting in a drastic change in the environment. For example, two waterways, *Veersche Gat* and *Grevelingmeer*, were disconnected from the North Sea in 1961 and 1971, respectively, by high sea walls. The resulting brackish lagoons exhibited entirely different habitats with less diversity than before their closure, thus greatly reducing the beneficial functions of the ecosystem. (van Westen, p. 22) Additionally, by disconnecting river outlets from the sea, the changing tides cannot flush sediment which collects along the river and is deposited at the river's mouth. This process can be extremely important in maintaining a healthy ecosystem when the sediment is laden with pesticides, industrial waste, or heavy metals. Pollution has long been a problem for the Rhine River, which passes through Germany's heavily-industrialized *Ruhrgebiet*. Without proper flushing, the collection of this pollution in the Netherlands would result in poor water quality. (van Westen, p. 22) Furthermore, there were many unexpected costs associated with the Delta Project. Maintanance costs were higher than expected, and there were unforeseen expenditures to restore natural habitats and fix water quality problems.

Nevertheless, there have been success stories as well. The creation of lakes behind sea walls has generated new economic opportunities for those regions, including recreation, fishing, and agriculture. By shortening the coastline by 800 kilometers and extending protected estuaries, a larger supply of fresh water became available to agriculture in the south. This allowed irrigation water to be redirected northward, where it was needed. (Waterland.net) Also, sea walls were often built with highways on top. These new highways have improved transportation between the many islands of Zeeland, some of which had been isolated for centuries. (Waterland.net)

Moreover, the Dutch have not entirely ignored the importance of a healthy environment throughout the Delta Project. In 1978 the Dutch government agreed to change the design for the Osterschelde Barrier to allow for greater tidal exchange. Instead of the impervious dike originally planned, a sluice system that could close during heavy storms was constructed. The change came as a result of the environmental movement of the 1970s and the environmental damage resulting from the Delta Project. As a result, the Osterschelde estuary has not experienced the same deterioration of natural habitat as *Veersche Gat* and *Grevelingmeer.* (van Westen, p. 22)

Changing Society, Changing Environment

"Trend is not destiny."
— René Dubois

The world in which the Delta Project was originally conceived exists no more. The people, economy, and environment of the Netherlands are changing, and these changes are having a profound impact on the Dutch flood mitigation program. The many components of the *Deltawerken* and the thousands of kilometers of dikes constructed along rivers are examples of the traditional technical measures[7] that the Dutch have built to protect themselves from high water by blocking it out. However, while these measures are extremely important to the continuing existence of the Netherlands, looming problems make them inadequate solutions for the future.

The need for land to house agriculture has been a driving force for land reclamation from the sea, and much area has been polderized to create arable land or grazing pastures. Agriculture is an extremely important component of the Dutch economy. In fact, the value of agricultural products exported annually by the Netherlands is the second highest in the world at $55 billion, exceeded only by the U.S., which exports $68 billion per year in agricultural products. More specifically, the country is a powerhouse in horticulture exports,[8] specializing in ornamental plants and bulbs. The Netherlands is the largest exporter of ornamental plant products, and 80 percent of all flower bulbs originate in the Netherlands. (Pinckaers, p. 4) Historically,

[7]Traditional technical measures will be defined here as any physical structures used to mitigate flooding, such as dikes, dams, canals, ditches, and pumping stations.

[8]Plants, flowers, vegetables, and fruit.

the meat and dairy industry has also contributed significantly to agriculture. However, the emergence of other accessible beef markets, such as Brazil which exports 10 million kilograms of beef annually to the Netherlands, has diminished the need for land-strapped countries like the Netherlands to produce meat and dairy products. (Cattlesite.com) This is significant because while only 8 percent of agricultural acreage is devoted to horticulture production, it comprises 41 percent of the value of Dutch agriculture. (Pinckaers, p. 6) As the Dutch agriculture sector becomes less dependent on meat and dairy production, the amount of land necessary will also decrease, thus decreasing agriculture's demand for land reclamation.

Just as the Dutch agricultural sector is changing, so is the environment. The Royal Netherlands Meteorological Institute (RNMI) projects that by the year 2100 average winter precipitation in the Netherlands will increase between 6 percent and 25 percent and that sea levels will rise between 20 centimeters and 110 centimeters. (Können, p. 2) Additionally, the Dutch land mass continues to sink at an average rate of 40 centimeters per century, due to the settling of drained peat soils and other geological processes. (Woltjer and Al, p. 214) The combination of rising sea levels and land subsidence is creating a growing gap between water and land elevations. Without major intervention, the important industrial and business centers of Amsterdam, The Hague, and Rotterdam are at risk. Additionally, the Netherlands is already a densely urbanized country with a continually growing population. According to a 2001 forecast from the Ministry of Housing, Spatial Planning and Environment, there will be a 33 percent increase in the amount of land needed for combined residential and commercial use by the year 2030. (Woltjer and Al, p. 215) Due to the combination of the continued growth of the Dutch economy and population and the ever-changing environmental conditions, it will be necessary for the Dutch to integrate sustainable practices into flood mitigation design to ensure continuing existence in a changing world. Additionally, it will become increasingly important to combine land uses to satisfy all needs. For example, by building floating homes, land might be used to both store water and provide housing, or by creating wetlands, land might serve to store water and provide a natural habitat. (Woltjer and Al, p. 214)

Following the construction of the dikes and barriers, the heightened sense of safety has encouraged increased urban development in former flood plains. Often there is a sense of absolute safety against flooding. In fact, if asked, most Dutch would say they rarely think about the threat of flooding in their daily lives. (Kuijpers, 2007) This sense of safety has created a dramatic development boom behind dike walls. As a result, estimated safety levels have become inaccurate. Referring back to Figure 2, the damage curve is shifted upward due to the increased value of the investments in the dike rings. That shift in turn increases the optimum dike heights necessary to maintain safety levels designated by the Delta Plan. The result are dike heights that have safety levels which are less than original Delta levels. Put simply, to maintain the desired safety levels, the dikes need to be raised further. To explain it in more technical terms, risk is usually defined as the probability of an unwanted event multiplied by its consequences, i.e. Risk = Probability x Effect. (Smits et al., p. 344) In the case of flooding risk analysis, risk would be the probability of a flood occurring multiplied by the damages caused by the flood. When this analysis is applied to post-Delta Netherlands, it shows that risk has increased. While the probability of a flood occurrence has decreased since 1953, because of greater development the levels of potential damages have increased dramatically. (Smits et al., p. 345)

A New Approach

"Nederland leeft met water."[9]

— Dutch flood awareness campaign slogan

Because conventional techniques would be too costly to combat flooding in light of the trends described in the previous section, a new committee — the Water Management in the Twenty-First Century Advisory Committee — was created in the spring of 1999. The Committee was charged with "making recommendations for desirable changes to the water

[9]Dutch for "The Netherlands lives with water."

management policy . . . , focusing on the consequences of climatic change, rising sea levels and land subsidence." ("A Different Approach to Water," p. 13) The Dutch Cabinet[10] responded with its own report entitled "A Different Approach to Water," in which the Cabinet states its position on water management for the next century. Combined, the reports concluded that water management and spatial planning[11] policies must change dramatically and that land must be "given back" to the water to insure safety. The Cabinet's document became the impetus for a number of new national policies, with many strengthening the link between spatial planning and water management. One such policy, described below, is arguably the biggest turning point in Dutch flood mitigation, as it focuses resources away from technical measures and toward policy-oriented approaches.

The national government publishes Special Planning Key Decisions (SPKDs) to establish a broad strategy for spatial planning. They include long-term goals and recommendations pertaining to spatial planning. Provinces use these SPKDs to create regional plans, which municipalities then use to create detailed land use plans. In 2006 the Dutch Cabinet approved a SPKD entitled *Ruimte voor de Rivier* (RvdR), or Room for the Rivers. RvdR aims to refocus attention from dike reinforcement to spatial planning. Instead of building large, expensive dikes, which attempt to control flood waters, specific areas of land will be allowed to flood. The main objectives of *Ruimte voor de Rivier* are to deepen the land neighboring rivers, displace dikes inland, and lower groynes[12] in rivers. The reinforcement of dikes will be a last resort if all other options are too expensive or inadequate. This approach accepts the reality that floods are inevitable.

Figure 3 presents an excellent example of the problem that many cities, such as Arnhem, are facing around the Netherlands. Urbanization has encroached and constricted the riverbanks, creating a bottleneck that amplifies flooding conditions. Seen in Figure 3, Arnhem is located at the confluence of the

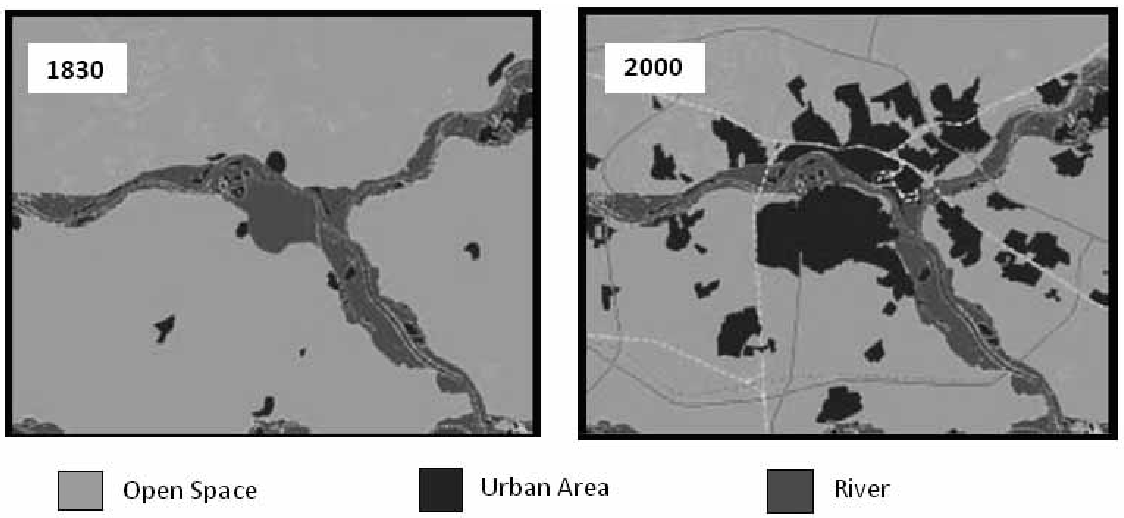
[10]The Dutch Cabinet is the main executive body of the Netherlands and consists of the ministers and state secretaries.

[11]Spatial planning, more commonly called land use planning in North America, refers to the practices and policies that influence the distribution of activities and development in a region.

[12]Groynes (or groins) are structures perpendicular to the riverbank which are built to catch sediment.

Figure 3

Urbanization around Arnhem



Source: "A Different Approach to Water," p. 44.

Neder-Rijn and *Ijssel* rivers. In 1830 these rivers formed a wide channel where flood waters could be dissipated. Over time, however, urban growth reclaimed much of the river's space, forcing its discharge to funnel through a bottleneck located in the center of the city. At this section of the river the water level during a flood becomes higher than it would in its natural state, inflicting greater damage. As climatic changes and increased precipitation cause greater discharges in the rivers, the safety level decreases. In cities like Arnhem, there is no room for the expansion of dikes. Instead, retention areas can be built upstream that will reduce the peak discharge and increase infiltration of that water into the ground. A number of pilot projects have been designed for the *Ruimte voor de Rivier* program, and the Cabinet has earmarked (2.2 billion for the measures in the plan. (*Ruimte voor . . .*)

A similar project to those planned in RvdR can be found in the Westerscheldt — the Dutch portion of the inlet to Antwerp — and may have served as a prototype for the SPKD. Centuries of dredging have deepened the channel to accomodate larger ships, which in turn increases the volume of water that moves through the inlet. Simultaneously, development has reclaimed portions of former flood plains, thus narrowing the space available through which the flood water can flow. The combination of more water moving through a smaller space creates higher water levels and, therefore, an increased risk of flooding. Furthermore, constructing a barrier was both financially and politically out of the question. (Smits et al., p. 348) Realizing this danger, in the early 1990s Dutch and Flemish authorities designed a solution which would return flood plains to the river. They termed the areas Controlled Inundation Areas. (Smits et al., p. 349) First, they built a new dike farther inland and then removed the old dike. Known as *ontpoldern*, or depolderizing, this practice is at the heart of *Ruimte voor de Rivier* and the future of Dutch flood management. One advantage of this strategy is an increased level of safety. The newly-formed flood plains and natural wetlands can absorb energy from storm surge or flood waves, dissipating their effect. Also, the watershed develops a greater capacity to hold water, which decreases discharge levels downstream. Additionally, the creation of new wetlands, which serve as parklands and wildlife reserves, develops ecological potential and recreational opportunities. (Smits et al., p. 349)

There are over two dozen locations throughout the Netherlands that will receive similar procedures as part of giving "room for the rivers." The primary focus will be on the Rhine and Meuse rivers and their tributaries. Scheduled to be completed in 2014, the *ontpoldern* of Overdiep polder will be the first project directed under *Ruimte voor de Rivier*. This polder is currently a 1400-acre island along the Bergse Meuse river (a tributary of the Meuse) with seventeen farms, a marina, and a military training base located on it. (Gagliano) The water-retaining dikes will be removed and the existing farm structures will be rebuilt on the top of 20-foot, 6-acre mounds. By depoldering Overdiep, the river will be able to flood the land occasionally, at an estimated average rate of once per 25 years. The result will be a drop in area water levels of up to 30 centimeters, which will be felt far downstream. (*Ruimte voor . . .*) The idea, by the way, is not new; during the Middle Ages many Dutch farmers lived on mounds, known as "terps," while their livestock grazed below. (Gagliano) In fact, it was the farmers of Overdiep who proposed this solution. Their other option would have been to accept compensation for their land and to desert their farms. Because agricultural land is at a premium in the densely-populated country, that option was undesirable.

Designing and implementing these policies within the Netherlands is not enough, though. International cooperation in implementing flood-related policies is paramount. All four major rivers which discharge into the Netherlands have watersheds that are located primarily outside the country. Excess water and pollution from other countries thus become a Dutch problem. To encourage international cooperation, the EU has designed the EU Water Framework Directive. Under this directive countries will work together on such programs as river widening.

In addition to the strategies for flood mitigation, the methods by which the Dutch analyze risk are changing, too. While the basic concept of cost-benefit analysis remains, its application has become more complex with the addition of improved technology and data.

Better understanding of dike failure mechanisms, as well as better modeling techniques, allow the Dutch to calculate more accurate estimates of the probability of dike failure. In its first applications, cost-benefit analyses only accounted for overtopping; today, engineers realize there are many other failure mechanisms for dikes, with the most critical being piping,[13] instability, erosion, and human error (e.g. not closing a sluice in sufficient time). With all possibilities of failure considered, the calculated risk of flooding increases.

Finally, because nearly all flood mitigation projects in the Netherlands fall under the public sector, it is very important to have public support and understanding. Realizing this, the Dutch government began a public awareness program in February 2003. ("Water in . . . ," p. 9) The goal of the program was to increase awareness in the Netherlands of the impact of climate change on flooding and the efforts of the Dutch government to solve these problems. Specifically, the programs introduced the new concept of "giving water more room" and encouraged support of it. To bolster awareness, the program also used a TV weatherman and self-proclaimed "water ambassador" named Peter Timofeef as spokesman. Making radio and television appearances and starring in cartoons, he comments on the problems and solutions associated with water. Additionally, during the Dutch presidency of the EU from July to December of 2004, 27 signs were erected at various locations which mark sea level. Tourists and residents alike gain a stronger understanding of the everyday vulnerability of the Netherlands this way. The program has been successful in raising awareness of the continual danger of flooding.

[13]The term "piping" refers to underground erosion that perpetrates from cracks or cavities as water infiltrates them. If the erosion is left unabated, it can cause instability in the dike's foundation.

Conclusion

The Dutch continue to be world leaders in flood protection. Their unique location between rivers and the sea has required them to constantly be innovative and aggressive. The battle against water has changed throughout history and the Dutch have continually adapted to new challenges. In today's world, where changes are occurring at an even greater pace, this ability to adapt becomes even more important. The past decade has seen a stark transition in Dutch national water management policy as a result of social and environmental pressures. The transition is not complete, however, and the keys to success will be the implementation of the policies and their adoption into engineering works. The effectiveness of new strategies will soon be tested, as such factors as climate change, rising sea levels, land subsidence, and expanded urbanization increase pressure on the system. These changes will have lasting effects on the Dutch landscape and society.

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